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Prospective Secondary Science Teachers' Argumentation Skills and the Interaction of These Skills with Their Conceptual Knowledge

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Abstract: This study investigated if prospective secondary science teachers enhance their argumentation skills and the interaction of the change in their argumentation skills with their conceptual knowledge during an argumentation-based guided inquiry course. 37 prospective secondary science teachers constituted the study sample. They were grouped according to whether or not they had a misconception about understanding of balanced forces at the beginning of the course. They performed oral and written argumentation tasks during the course. Their written argumentation tasks were assessed four times during the course for balanced forces and sinking and floating behaviour of objects. Results indicated that prospective secondary science teachers developed mostly counter-argument and rebuttal skills. In addition, different trends of the change in argumentation skills were identified for prospective secondary science teachers having a misconception and those having a scientific conception. Implications for teacher education and science education were discussed according to these results.

Introduction

Recent approaches in science education have emphasized the importance of fostering argumentation in science classrooms (Trend, 2009). It has been claimed that fostering argumentation would enhance student scientific reasoning which was lacking in most science classrooms (Fleming, 1986; Kelly, Druker, & Chen, 1998; Kuhn ,1993). This emphasis is in alignment with the focus of US and European organizational documents in which critical thinking was stressed to be an essential component of science education (American Association for the Advancement of Science, 1993; National Research Council, 1996; Organisation for Economic Co-operation and Development, 2001).

Arguing between alternative theories, i.e., argumentation was viewed to be a necessary part of the scientific enterprise by philosophers of science (Kuhn, 1996; Root-Bernstein, 1989). Scientists' commitment to a theory was criticized in that this commitment can cause a delay in acceptance of a more scientific theory from this perspective. In fact, hypothetico-deductive argumentation has been recognized to be the essence of scientific reasoning (Giere, 1984, Lawson, 2003; Popper, 1968).

The importance of arguing between alternative positions was also emphasized in developmental psychology for the refinement of theory and evidence coordination (Kuhn, 1991, 1993). Results of these studies showed that subjects who could argue between different positions were more able to differentiate their theories from evidence. Furthermore, they demonstrated that subjects who ignored other alternatives in their arguments mostly used theory-oriented evidence to support their claims. To address these reasoning problems in science classes, it was suggested that students should be provided with contexts in which they can argue for different positions (Kuhn, 1993).

Toulmin's argument pattern (TAP) (1958) has been used in science education to model and assess student argumentation. Numerous studies adopted TAP to assess student arguments in science classes (e.g., McNeill, Lizotte, Krajcik, & Marx, 2006; Osborne, Erduran, & Simon, 2004; Zohar & Nemet, 2002). However consideration of the other alternatives has been neglected in TAP (Nussbaum, 2011). In fact one needs to evaluate, weigh, and combine arguments and counter-arguments for an effective argumentation (Nussbaum, 2011). Herein, Nussbaum and Schraw (2007) proposed argument--counter-argument integration for a well-developed argumentation schema. Studies showed that instructions which were based on argument--counter-argument integration facilitated more integrative arguments among students (Nussbaum & Edwards, 2011; Nussbaum & Schraw, 2007).

Competing Theories Teaching Strategy (CTTS) is an instructional strategy through which students are fostered to argue between different alternatives. More clearly, they are encouraged to argue between alternatives by constructing arguments, counter-arguments, and rebuttals using data (Osborne et al., 2004). In this regard, CTTS fits nicely with the concept of argument--counter-argument integration. In this research, we incorporated CTTS to an undergraduate physics by inquiry course to develop argumentation skills of prospective secondary science teachers (PSSTs). In addition, we analysed the argumentation skills of PSSTs four times during the course which enabled us to examine the interaction between student conceptual knowledge development and the change in PSSTs' argumentation skills.

In the following sections, first we stated the roots of argumentation in the history of science and developmental psychology. Second we defined TAP, its applications in science education, and stated its limitations. At this point, we proposed to use CTTS, which addresses one of the limitations of TAP, in science classes. Third we discussed about studies which focused on fostering argumentation in teacher education programs. Fourth we attempted to explicate the link between conceptual knowledge and argumentation. Finally, we stated our research questions.

Literature Review

Argumentation

Philosophers of science emphasized the importance of argumentation involved in weighing and comparing different alternative theories for the development of science (Kuhn, 1996; Root-Bernstein, 1989). Hence cycles of hypothetico-deductive reasoning and selection of a theory that is superior to other rival theories were recommended for a qualified scientific argumentation (Giere, 1984; Lawson, 2003, 2005).

Findings of both cognitive psychology and science education showed that subjects who were dependent on their theoretical beliefs demonstrated reasoning flaws when they had argued between different alternative theories (Kuhn, 1991; Kuhn, Amsel, & O'Loughlin, 1988; Kuhn, Schauble, & Garcia-Mila, 1992; Zeidler, 1997). Mostly they had difficulty in the differentiation of theory and evidence (Kuhn, 1993). However subjects, who could offer evidence that was not theory oriented, were more able to coordinate their theories with evidence (Kuhn, 1993; Kuhn et al., 1992). Accordingly, these latter subjects were more competent in arguing between different alternatives (Kuhn, 1991; Kuhn et al., 1988; Kuhn et al., 1992). Studies in science education showed that students mostly relied on their beliefs when they argued between alternative theories (Sadler, Chambers, & Zeidler, 2004; Zeidler, Walker, Ackett, & Simmons, 2002). In addition, they solely relied on scientific authorities without scrutinizing the data (Kolsto, 2001). As a remedy to these problems, providing students contexts where they can argue between different alternatives was recommended (Acar, 2008; Kuhn, 1993; Osborne et al., 2004).

It is worth noting what "argument" and "argumentation" was conceived in the present study. Inspired by Kuhn (1993) and Kuhn and Udell (2003), an argument was conceived as a product of one's attempt to support a claim about an issue. On the other hand, we referred to reasoning between alternatives when we used the term "argumentation" which can be an individual reasoning between different alternatives or group discussion on different viewpoints.

TAP and CTTS

Argumentation theory emerged from a need to model arguments in everyday contexts in which conclusions cannot be drawn from premises analytically (Hintikka, 1999; van Eemeren et al.,1996). From this perspective, Toulmin (1958) offered a pattern of argument, i.e., TAP, that can be used to model and assess arguments in practical situations (Toulmin, Rieke, & Janik, 1984). According to Toulmin (1958), a simple layout of an argument consisted of data, warrant, backing, and claim. Data were the observations or facts that can be used to support a claim. A warrant was a reasoning that serves as a connection between data and the claim. Backing was a basic assumption in a domain that serves as a justification for the warrant. Finally, a claim was a conclusion stating one's stance on an issue. In more advanced arguments, qualifiers and rebuttals can also be used (Toulmin, 1958). A qualifier was a statement that specifies the conditions under which the claim is true and a rebuttal was a statement that indicates the circumstances under which the claim is wrong.

TAP has been used both as an assessment template for student arguments and as an instructional tool to teach reasoning in science classrooms. Studies, which focused on the former usage of TAP, found that students barely used evidence and justification to support their claims (Jimenez-Aleixandre, Rodriguez, & Duschl, 2000; Kelly et al., 1998; Watson, Swain, & McRobbie, 2004). Studies, which focused on the latter usage, showed that explicating the components of TAP to students helped them improve their arguments (Bell & Linn, 2000; Sandoval & Millwood, 2005; Zohar & Nemet, 2002).

Rationale of CTTS rooted in philosophy of science and cognitive psychology both of which had emphasized the necessity of arguing between different alternative theories for a quality argumentation. In addition, research on students' misconceptions created the ground work for CTTS in which these conceptions have been used as alternative explanations (Acar, 2008; Brewer, 1999; Kuhn, 1993).

Students have been provided with alternative explanations and evidence about a scientific phenomenon in CTTS. Students have then been encouraged to argue between these alternative explanations using evidence. Student argumentation quality in CTTS has depended on how they constructed counter-arguments and rebuttals which indicated their competence on reasoning between alternatives (Chinn & Buckland, 2012; Nussbaum, Sinatra, & Poliquin, 2008; Osborne et al., 2004). Research showed that CTTS was an effective strategy to develop student counter-arguments and rebuttals (Acar, 2008; Osborne et al., 2004).

Argumentation Instruction in Preservice Teacher Education

Several studies provided workshops to in-service science teachers for fostering their pedagogical knowledge about argumentation (Simon, Erduran, & Osborne, 2006; Zohar, 2004). However even teachers who attended to these workshops were found to be reluctant to apply argumentation practices in their classes (Zohar, 2004). This fact can be explained by their negative beliefs on teaching higher order thinking skills which had been formed through their schooling years (Zohar, 1999). Therefore, more emphasis should be given to developing procedural and pedagogical knowledge related to argumentation in science teacher education programs. However limited study has existed in the literature with this research focus.

Argumentation was integrated to science teaching methods courses in preservice teacher education programs by providing either argument scaffolds (Zembal-Saul, Munford, Crawford, Friedrichsen, & Land, 2002) or argument frameworks (Zembal-Saul, 2009). The findings suggested that if appropriate argument scaffolds are provided to preservice teachers, their evidence-based arguments may be enhanced (Zembal-Saul et al., 2002). In addition, it was indicated that argument frameworks can assist preservice science teachers in focusing their attention to evidence-based explanations (Zembal-Saul, 2009). Based on these results, Zembal-Saul et al. (2002) recommended that student teachers should have opportunities to learn science in ways that reflect effective and reform-based pedagogies in teacher education programs. Moreover, Zembal-Saul (2009) recommended fostering evidence-based explanations earlier in preservice teacher education programs for helping student teachers adopt more informed teaching about argumentation. In fact, Avraamidou and Zembal-Saul, (2010) found that a first year elementary science teacher, who had taken evidence-based inquiry courses in a teacher education program, was more skilful in scaffolding her students' arguments than another first year elementary science teacher who had not taken similar courses.

Although the mentioned efforts were taken mostly to enhance preservice science teachers' pedagogical knowledge about argumentation, little space was given to student teachers practice and enhance their argumentation skills. However *knowledge of elements of thinking* (Zohar, 2013) is an essential component of pedagogical knowledge in the context of teaching higher order thinking (Zohar & Schwartzer, 2005). From this perspective, fostering argumentation among PSSTs is essential since these students will scaffold their student argumentation in science classes as professionals.

The Relation between Conceptual Knowledge and Argumentation

Recent approaches in developmental psychology have stressed the interdependence of content-dependent and content-independent features of reasoning skills (Zimmerman, 2000). Content-independent features consisted of reasoning skills (e.g., hypothetical reasoning, controlling of variables, proportional reasoning) that can be applied across domains. On the other hand, content-dependent features were mostly associated with domain-specific knowledge (Zimmerman, 2000).

Several studies in argumentation focused on the relation between reasoning skills and conceptual knowledge (e.g., Hogan, 2002; Sadler & Zeidler, 2005). Results showed that if subjects had high content knowledge about a topic, they demonstrated fewer reasoning flaws (Sadler & Zeidler, 2005) and more integrated decision making (Hogan, 2002).

Several studies focused on the change of conceptual knowledge or argumentation skills in argumentation instruction. For instance, Nussbaum et al. (2008) showed that argumentation instruction can help students change their conceptions. Furthermore, results in Zohar and Nemet (2002) indicated that it is possible to develop argumentation skills in two different contexts: one where one's conceptual knowledge plays a significant role in argumentation, i.e., science contexts, and another where one's conceptual knowledge does not have that effect, i.e., everyday issues. In spite of the significant effect of conceptual knowledge on argumentation in scientific issues, little has been done to examine how argumentation skills, i.e., argument, counter-argument, rebuttal evidence and justification skills, change as students develop their conceptual knowledge. To address this gap, Acar (2008) analysed students' argumentation skills as they developed their conceptual knowledge in an argumentation-based inquiry course. Acar (2008) found that students' development of counter-argument and rebuttal justification skills were more related to conceptual knowledge development during the course. In addition, Acar (2008) demonstrated that students' counter-argument and rebuttal evidence skill development were not necessarily related to conceptual knowledge gain.

Problem Statement

Although argumentation was incorporated to science teaching methods courses in teacher education programs (e.g., Zembal-Saul, 2009; Zembal-Saul et al., 2002), little has been done for the incorporation of argumentation to introductory science courses. Incorporation of argumentation to science teaching method courses is important for fostering PSSTs' pedagogical knowledge about argumentation. However more is needed to address their procedural knowledge about argumentation before they learn how to teach argumentation. PSSTs should be equipped well with constructing quality arguments and arguing between different alternatives so that they can better scaffold their students' argumentation in science classrooms in the future (Avraamidou & Zembal-Saul, 2010; Zohar, 2013; Zohar & Schwartzer, 2005).

Another neglected issue in the literature relates to the investigation of the interaction between the change of argumentation skills and student conceptual knowledge during an argumentation-based science instruction. Acar (2008) examined how student argumentation skills changed before and after students learned the scientific content of their argumentation during an argumentation-based guided inquiry course. Besides Nussbaum et al. (2008) showed that argumentation instruction helped students change their misconceptions. However no attempt was taken to examine how argumentation skills of students having different initial conceptual knowledge change during argumentation-based instruction. In fact previous research showed a strong relationship between argument quality and conceptual knowledge (e.g., Sadler & Fowler, 2006; Sadler & Zeidler, 2005). Furthermore, a strong negative relationship was demonstrated between one's misconception and his/her reasoning level (Lawson & Weser, 1990; Lawson & Worsnop, 1992). More specifically, Acar (2014) demonstrated that there were conceptual knowledge and scientific reasoning differences between students who had a consistent misconception and those who did not. As argumentation is evidence-based reasoning (Acar et al., 2010) and relates to conceptual knowledge, it is hypothesized in this research that trend of the change in argumentation skills in an argumentation-based instruction will be different for PSSTs having a misconception and those having a scientific conception. Explication of this trend for each group may help educators to address each group's need in argumentation skills and accordingly design the instruction with regard to argumentation and conceptual knowledge. To address this gap in the literature, we utilized a time series design. We categorized PSSTs based on whether or not they had a misconception about understanding of balanced forces. Then we investigated the change in argumentation skills of these two groups before and after instruction on balanced forces. We examined the following research questions in the present study to address these gaps in the literature:

1. Can prospective secondary science teachers develop their argumentation skills in an argumentation-based guided inquiry physics course?
2. What is the interaction between change of argumentation skills and conceptual knowledge for prospective secondary science teachers having a misconception and those having a scientific conception during an argumentation-based guided inquiry physics course?

Method

Research Sample

PSSTs (*N* = 37) enrolled in a Physics by Inquiry (PbI) course at a Midwestern US university constituted the study sample. Although there were a total of 125 PSSTs in the PbI course, 37 PSSTs remained in the study sample after a list-wise deletion of missing subjects who did not complete all the argumentation tasks. PSSTs enrolled to this course to fulfil their science credit requirement for graduation. PbI was offered to freshman undergraduate students who wanted to specialize in teaching science to middle school students. There were not pre-requirement of any physics course for the enrolment to PbI. As state requirements mandated, PSSTs had to get a Master of Education degree after they had received a Bachelor degree for becoming a middle school science teacher. If a PSST completed courses successfully, he/she would have taken the bachelor degree in 4 years.

We grouped PSSTs under having a misconception or not according to their arguments at the first balancing written argumentation task for the examination of the second research question. Accordingly, 18 PSSTs were categorized as students having a misconception and 19 PSSTs were grouped under students having a scientific conception about balanced forces.

Instruction

The duration of the instruction was 10 weeks. PSSTs met twice a week for a total of six hours per week. During the instructional period, PSSTs worked in small groups consisting of three to four members. They performed guided experiments and did exercises from the Physics by Inquiry (PbI) Textbook (McDermott, 1996, Volume 1). There were eight instructors in the course: One professor of physics, two senior instructors, two teaching assistants, and three senior undergraduate majors who had successfully completed the course in previous years. There were morning, afternoon, and evening sections in the PbI course. The professor of physics taught in morning and afternoon sections. One senior instructor taught in all sections. The other senior instructor taught in afternoon section. One of the teaching assistants taught in morning and evening sections. The other teaching assistant taught in only evening section. Each senior undergraduate student taught in only one section. In sum, a total of three experts and a senior undergraduate student taught in each section.

Mass, volume, balancing, density, buoyancy, heat and temperature concepts were taught in the course. PSSTs first performed the experiments and exercises in small groups during instruction. Then each small group discussed the guiding questions in the PbI textbook which followed after each experiment and exercise. Finally, they strived to agree on a shared meaning. PSSTs' learning was checked by instructors continuously during these processes. When a small group finished its work, they put a check point flag on their table which meant that they were ready for instructors' check. Then, they were checked by an available instructor. Instructors asked each PSST in small groups the reasoning they used and the conceptual learning that they gathered when they were performing the experiments and exercises during these check points. In this way, these checks points provided instructors a chance to correct any misunderstanding or fallacious reasoning. No lecturing took place in these instances. Rather instructors guided PSSTs' learning by asking leading questions. For example, PSSTs in a small group did several controlled experiments to test if the shape of the objects effects buoyancy in water before one of these check points. One instructor showed that ball-shaped clay sank in water whereas the boat-shaped clay floated. Then he asked if the shape of the objects affects buoyancy. After a group member approved, the instructor put paper clips with different shapes into the water. After PSSTs observed that all paper clips sank, instructor again asked if the shape of the objects effects buoyancy. Here the instructor's intention was to direct PSSTs' learning from shape to volume of the object. In the next experiments, PSSTs trialled if mass or volume of the objects affected their buoyancy in water. After they had discovered that both mass and volume of the objects were responsible for their buoyancy behaviour, they did experiments using different liquids to understand the effect of a liquid's density on an object's buoyancy. As can be seen from this example, instructors provided chances to PSSTs for gaining scientific concepts and reasoning on their own in the PbI course.

Argumentation Tasks

Oral and written argumentation tasks for the balancing and buoyancy concepts were constructed. CTTS was used to foster argumentation of PSSTs during these tasks. Two hypothetical students were presented as supporting alternative explanations about balancing and buoyancy concepts at these tasks. Visual data were also provided to PSSTs. PSSTs' arguments, counter-arguments and rebuttals were then encouraged.

Each small group first discussed the hypothetical students' controversy on balancing and buoyancy and then instructors checked PSSTs' argumentation in two oral argumentation tasks. Instructors stimulated and clarified PSSTs' reasoning by asking "why?" and "what do you mean?" questions at the check points of these tasks. If an instructor had received satisfactory responses from a small group at each check point then he/she marked the checklist for this small group. Furthermore, PSSTs answered structured questions individually provided in student worksheets at four written balancing and buoyancy argumentation tasks (AT_1, AT_2, AT_3, AT_4). Each oral task lasted about half an hour and written task lasted about an hour. Thus PSSTs spent approximately 5 hours finishing the oral and written argumentation tasks. Sequence of the administration of argumentation tasks during instruction can be seen at Fig. 1.

1^{st} week	2^{nd} week	3^{rd} week	6^{th} week	7^{th} week	10^{th} week
Balancing and Buoyancy AT_1	Balancing Oral Argumentation Task	Balancing and Buoyancy AT_2	Buoyancy Oral Argumentation Task	Balancing and Buoyancy AT_3	Balancing and Buoyancy AT_4

Figure 1: Time sequence of written and oral argumentation tasks during the course

Two alternative explanations regarding balancing and buoyancy were presented in each of the written argumentation tasks (see Appendix A for an example of written argumentation task). Only mass of the objects, and both mass and distance of the objects from the fulcrum effect balancing were presented as two alternative balancing explanations. Moreover, only mass, and both mass and volume account for objects' buoyancy in water were provided as buoyancy explanations. One explanation contained a misconception however the other can be identified as scientific conception in both balancing and buoyancy tasks. For prevention of any effect of explanation statement on PSSTs' decision, scientific terminology was avoided in the construction of these explanations. Both written balancing and buoyancy argumentation tasks were administered simultaneously four times during the course (see Fig.1). Balancing and buoyancy written argumentation tasks 1 (AT_1) were exactly the same as written argumentation tasks 4 (AT_4). More clearly, hypothetical students' explanations and data were identical at AT_1 and AT_4. Although hypothetical students' explanations were also same at written argumentation task 2 (AT_2) and 3 (AT_3), different data were presented to PSSTs in these tasks to avoid any possible carry-over effect.

PSSTs' construction of arguments, counter-arguments, and rebuttals were fostered in written argumentation tasks (see Appendix A for an example). First PSSTs were asked to indicate which hypothetical student explanation they agreed with (argument). Second, PSSTs were fostered to make an argument for the hypothetical student explanation that they did not agree with (counter-argument). Finally, PSSTs were encouraged to refute the hypothetical student explanation which they did not agree with (rebuttal). More importantly, PSSTs were fostered to use data and justifications at each of these steps.

PSSTs were grouped under students having a misconception (SHAM) and students having a scientific conception (SHAS) for their arguments at balancing AT_1 for a deeper examination of the interaction between the change in argumentation skills and conceptual knowledge. More specifically, SHAM argued for a naïve explanation, counter-argued for a scientific explanation, and rebutted the scientific explanation at AT_1 (see Tab. 1 for an example). On the other hand, SHAS argued for a scientific explanation, counter-argued for a naive explanation, and rebutted the naive explanation at AT_1 (see Tab. 2 for an example).

Argumentation Skill	Student Response
Position on the controversy	I agree with student A (hypothetical student who supports the naive explanation) that both sides should be equal and the object (should) be symmetrical for the fulcrum to be in the center of two sides.
Argument Evidence	Observation 3 (A baseball bat balances on a person's finger).
Argument Justification	His justification would be that since the baseball bat is skinner on one end and fatter the other, its fulcrum would be toward the thicker end of the bat.
Counter-Argument Evidence	Observation 4 (A huge cup is placed at the left end of the seesaw. Three people who have equal masses balance this cup. The first person is at the right end of the seesaw).
Counter-Argument Justification	Well since the cup is heavier than one person, it sits on the farthest end of the seesaw; whereas, the third person must sit closer to the center of the seesaw all the way out to the end.
Rebuttal Evidence	Observation 1 (A tightrope walker balances on a rope).
Rebuttal Justification	**The tightrope walker did not fit with student B's theory (hypothetical student who supports the scientific explanation).**

Table 1: Responses of a SHAM at AT_1

Argumentation Skill	Student Response
Position on the controversy	I agree with student B's claim more than I do with student A's claim. Balancing does depend on the distances from the fulcrum of each side, as well as the mass on each side. If one side has more mass than another, then the more massive side will need to be closer to the fulcrum than the other side.
Argument Evidence	A huge cup is placed at the end of a seesaw and it takes 3 people of equal masses to balance this cup, and a baseball bat balances on a finger.
Argument Justification	The mass of one side of the bat is bigger than the other end therefore having less distance from the fulcrum compared to the other side (mentioning about baseball bat example). If the three people are looked at as one whole object, then there is obviously less distance from the fulcrum on the side containing people than there is on the side with the cup (writing about seesaw example).
Counter-Argument Evidence	A ruler balancing on a person's finger, and a baseball bat balancing on a person's finger.
Counter-Argument Justification	The ruler is symmetric and therefore the fulcrum is at the center which makes the two sides equal (masses) and balanced. The baseball bat is asymmetric and therefore the fulcrum is closer to the more massive part making both sides of the balance have equal masses.
Rebuttal Evidence	Observation 4 (seesaw example).
Rebuttal Justification	Student A's explanation would have required the fulcrum to move closer to the cup as opposed to the objects (3 people) moving closer to the fulcrum.

Table 2: Responses of a SHAS at AT_1

Data Collection and Analyses

TAP was used to code PSSTs' arguments, counter-arguments, and rebuttals in each of the written argumentation tasks. Mostly, TAP was utilized to assess the structure of student arguments in science education (e.g., Jimenez-Aleixandre et al., 2000; Kelly et al., 1998). However recent studies have also emphasized a need for domain-specific tools to assess the quality of arguments (Kelly & Takao, 2002; Sampson & Clark, 2008; Sandoval & Millwood, 2005; Zohar & Nemet, 2002). Since the present study's research questions were related to PSSTs' development of argumentation skills and the interaction between conceptual knowledge and argumentation change, the quality of the arguments was also considered at the construction of the rubrics. That is to say, both conceptual quality and sufficiency of evidence and justifications were considered in the development of these rubrics. In addition, student counter-arguments and rebuttals, which were neglected in TAP (Nussbaum, 2011; Osborne et al., 2004), were also assessed. Our aim in CTTS was to foster PSSTs' use of evidence and justifications in each of the argumentation skills, i.e., argument, counter-argument, and rebuttal. Therefore TAP enabled us to assess PSSTs' use of evidence and justifications in each of the argumentation skill.

Score	Description
0	No evidence or wrong evidence
1	Citation of or reference for 1 correct piece of evidence [a]
2	Citation or reference for 2 correct pieces of evidence [b]

Table 3: Evidence scores for PSSTs' arguments, counter-arguments, and rebuttals (Acar, 2008, pp. 67-68)

[a] Citation of or reference for 1 correct piece of outside evidence i.e., evidence not provided for the argumentation tests, was coded as 1 for rebuttal evidence scores. [b] Citation or reference for 1 correct piece of evidence was coded as 2 for rebuttal evidence scores.

Score	Description
0.5	No or wrong justification
1.0	Vague justification, irrelevant justification [a]
1.5	A general justification for 3 or more observations which fits scientifically for some of the observations but not all of them
2.0	A general justification for 2 or more observations which fits scientifically for all of them
2.5	A justification that refers to an observation and scientifically incomplete or has some scientifically correct part and scientifically incorrect part.
3.0	A justification that refers to an observation and scientifically correct

Table 4: Justification scores for PSSTs' arguments, counter-arguments, and rebuttals (Acar, 2008, p. 69)

[a]In addition to the vague and irrelevant justifications, a score of 1 was given for PSSTs' rebuttals to justifications that had generalizability concerns for the hypothetical students' arguments.

Two rubrics were developed to assess evidence and justifications of PSSTs' arguments, counter-arguments, and rebuttals (see Acar, 2008 for detail). Initially, general patterns in PSSTs' use of evidence and justifications were identified for their arguments, counter-arguments, and rebuttals. Then, special cases that did not fit into this general pattern were identified and accordingly rough rubrics were revised. Final rubric for evidence can be seen in Tab.3 and justification can be seen in Tab.4. As can be seen from Tab.3, PSSTs could have an evidence score between 0 and 2. Examples of evidence and justification coding according to these rubrics can be seen in Tab.5 and 6 respectively.

Score	Description
0	Student B's justifications would mainly involve the masses on each side of the fulcrum. [a]
1	Student B would argue their position based on the fact that the 3 people (referring to an observation in which three people and a huge cup balance on a seesaw) must sit closer to the fulcrum to balance the cup. [a]
2	Both sides of the ruler (referring to an observation in which a ruler is balanced on a person's finger) have equal mass and equal distance, so it is balanced. The bat is balanced due to more mass on the right side and is closer to fulcrum. [a]

Table 5: Coding examples for evidence

[a] In making an argument for a hypothetical student who states both mass and distance affect balancing.

Score	Description
0.5	Full popcan (referring to a soda can that is balanced on its edge) has equal mass on both sides with fulcrum in the middle. [a]
1.0	For 4 (referring to an observation in which the sinking and floating behavior of sand grains and a block of wood is shown), the sand + (and) wood have diff. (different) masses + (and) volumes so they behave differently. [b]
1.5	I do agree with student B. I did not choose student A because student A does not talk about the volume or density being important when an object sinks or floats. Observations 1 (buoyancy behavior of full coke and diet coke cans in water with different masses), 3 (buoyancy behavior of ball and boat- shaped clays in water with same masses) and 4 (buoyancy behavior of sand grains and a block of wood in water with different masses) do not fit with student A's argument because the masses are the same. [b]
2.0	A (hypothetical student A) would say that in 1 + (and) 2 (buoyancy behavior of full coke and diet coke cans, and five blocks having the same volume but different masses) the objects that sank must be heavier than the ones that floated. [c]
2.5	In observation 3 (talking about the observation in which two weights, having different heights from the ground, are balanced on a pulley), the objects are the same size, but A is heavier, so it has less distance from the fulcrum and it is balanced. [d]
3.0	Student B would justify by the baseball bat (referring to observation in which a baseball bat is balanced on a finger), the mass not the same, it involves the distance, as well. They are distances from the fulcrum and they balance b/c (because) turning effects (of both sides) are different. [d]

Table 6: Coding examples for justification

[a] Making a counter-argument for a hypothetical student who states only mass of the objects account for balancing. [b] Making a rebuttal for a hypothetical student who states only mass accounts for an object's buoyancy behavior. [c] Making a counter-argument for a hypothetical student who states only mass accounts for an object's sinking and floating behavior. [d] Making an argument for a hypothetical student who states both mass and distance from the fulcrum affect objects' balance.

Justifications for each piece of evidence were scored separately. Since PSSTs could cite two evidences to get a maximum for argument and counter-argument evidence score, PSSTs' argument and counter-argument justification scores had a range from one to six depending on the number of evidence they cited. Besides PSSTs' rebuttal justification score had a range from 0.5 to 3 because PSSTs had a maximum evidence score for just referring to a piece of evidence. We preferred to score 0.5 instead of 0 for wrong justifications because we did not want to give a student 0 who wrote a wrong justification that still had some correctness. Initially, first author of this paper scored written argumentation tasks using these rubrics. Then, a graduate student from physics scored 20% of the total written argumentation tasks for establishing inter-rater reliability. Since argumentation tasks one and four were the same, inter-rater reliabilities for these tasks were reported as one (see Tab.7). A discussion was held between two coders to resolve the disagreements. After both coders agreed on a score, then this score was used for final analyses.

	AT_1 and AT_4		AT_2		AT_3	
	Evidence	Justification	Evidence	Justification	Evidence	Justification
Balancing	.95	.93	.91	.88	.85	.81
Buoyancy	.93	.90	.94	.92	.88	.85

Table 7: Inter-rater reliability scores for written argumentation tasks

To gain insight to the factors affecting development of argumentation skills, a small group's conversation was audio-taped when this group's reasoning and understanding were checked by an instructor after balancing oral argumentation task. This audio-tape was transcribed and then analysed for factors that can lead to the development of argumentation skills.

Results

R.Q.1: Can Prospective Secondary Science Teachers Develop Their Argumentation Skills in an Argumentation-Based Guided Inquiry Physics Course?

Change of argumentation skills was scrutinized between AT_1 and AT_4 for balancing and buoyancy concepts. Descriptive statistics of argumentation skills can be seen in Tab.8. One repeated measures Multiple Analyses of Variances (MANOVA) was performed for each concept. Time was the within subject factor and argumentation scores were the dependent variables in these analyses.

	Balancing AT_1		Balancing AT_4		Buoyancy AT_1		Buoyancy AT_4	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Argument Evidence	1.30	0.74	1.38	0.89	1.28	0.87	1.56	0.64
Argument Justification	3.34	1.55	3.39	1.63	2.94	1.65	3.76	1.63
Counter-Argument Evidence	1.32	0.71	1.39	0.79	1.03	0.73	1.53	0.64
Counter- Argument Justification	2.89	1.34	3.81	1.63	2.85	1.39	4.04	1.34
Rebuttal Evidence	0.76	0.93	1.38	0.92	1.22	0.92	1.36	0.89
Rebuttal Justification	1.05	0.66	1.83	0.86	1.77	0.77	2.15	0.69

Table 8: Descriptive statistics of argumentation skills at pre and post argumentation tasks

First MANOVA result showed overall balancing argumentation scores changed significantly from AT_1 to AT_4 (F (6, 31) = 4.84, $p < .001$). However, as can be seen from Tab.9, results of the follow-up Analyses of Variances (ANOVAs) showed argument evidence and justification, and counter-argument evidence scores did not change ($p > .05$ for each analysis). Moreover, counter-argument justification, and rebuttal evidence and justification scores increased significantly from AT_1 to AT_4 ($p < .01$; $p < .01$; $p < .001$respectively).

	F	*df*	*p*
Argument Evidence	0.27	1, 36	.608
Argument Justification	0.03	1, 36	.860
Counter-Argument Evidence	0.18	1, 36	.671
Counter-Argument Justification	9.12	1, 36	.005
Rebuttal Evidence	12.05	1, 36	.001
Rebuttal Justification	19.99	1, 36	.000

Table 9: ANOVA results for change in balancing argumentation scores from AT_1 to AT_4

Result of the second MANOVA demonstrated that buoyancy argumentation scores changed significantly from AT_1 to AT_4 (F (6, 31) = 4.30, $p < .01$). However, as can be seen in Tab. 10, results of the follow-up ANOVAs indicated that argument and rebuttal evidence scores did not change ($p > .05$ for each analysis). Nevertheless argument justification, counter-argument evidence and justification, and rebuttal justification scores developed over time ($p < .05$; $p < .001$; $p < .001$;$p < .05$ respectively).

	F	*df*	*p*
Argument Evidence	2.94	1, 36	.095
Argument Justification	5.64	1, 36	.023
Counter-Argument Evidence	18.58	1, 36	.000
Counter-Argument Justification	19.14	1, 36	.000
Rebuttal Evidence	0.66	1, 36	.421
Rebuttal Justification	5.12	1, 36	.030

Table 10: ANOVA results for change in buoyancy argumentation scores from AT_1 to AT_4

In sum, mostly PSSTs' counter-argument and rebuttal skills improved for balancing and buoyancy concepts. We relate this result to the effect of providing PSSTs written scaffolds both in written and oral argumentation tasks and providing teacher scaffold after oral argumentation tasks. More clearly, PSSTs were required to use evidence and justifications for their counter-arguments and rebuttals in both written and oral argumentation tasks by the use of written scaffolds (see Appendix A). Similarly, PSSTs received teacher scaffolds in the form of prompting questions. As can be seen from the following excerpt, an instructor fostered PSSTs to use evidence and justifications:

Instructor: *Which observations student 1 (hypothetical) would use to support his position?*
PSST 1: *Observations b (a balance balances on a table) and c (a seesaw balances on ground).*
Instructor: *Why?*
PSST 1: *Because the fulcrum is in the middle for all of them.*
PSST2: *(adds) And they balance.*

In addition, the same instructor fostered PSSTs to reason for both alternative explanations about how objects balance. Following excerpt was an example for this situation:

Instructor: *Okay, how would each student use these observations to justify their positions?*
PSST2: *Student 1 (hypothetical) would say that like seesaw where fulcrum is in The middle that pretty much what he was saying fulcrum has to be in the middle.*
Instructor: *Okay, what about student 2 (hypothetical student)?*

PSST 1: *They are all balanced and they are not all in the middle just like that?*
PSST 3: *But the distance and the masses (of each side) should be equal (for that hypothetical student's argument).*

R.Q.2: What is the Interaction between Change of Argumentation Skills and Conceptual Knowledge for Prospective Secondary Science Teachers having a Misconception and Those having a Scientific Conception during an Argumentation-Based Guided Inquiry Physics Course?

PSSTs were categorized under two groups, i.e., Students Having a Misconception (SHAM) and Students Having a Scientific conception (SHAS) about balancing, based on their responses to AT_1. As PSSTs were instructed about balancing just before they performed AT_2, change of argumentation skills was analysed first from AT_1 to AT_2 and then from AT_2 to AT_4. Descriptive statistics of SHAM and SHAS groups' argumentation skills can be seen in Tables B1 and B2 at Appendix B respectively. Change of SHAM and SHAS groups' argumentation skills' means over four argumentation tasks can be seen in Fig. 2 and 3 respectively.

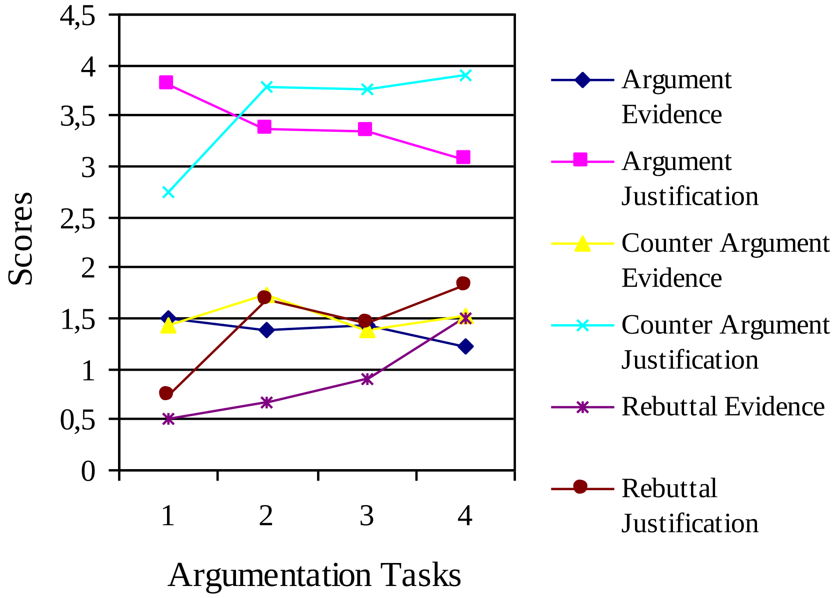

Figure 2: SHAM group's argumentation skills' mean change over argumentation tasks

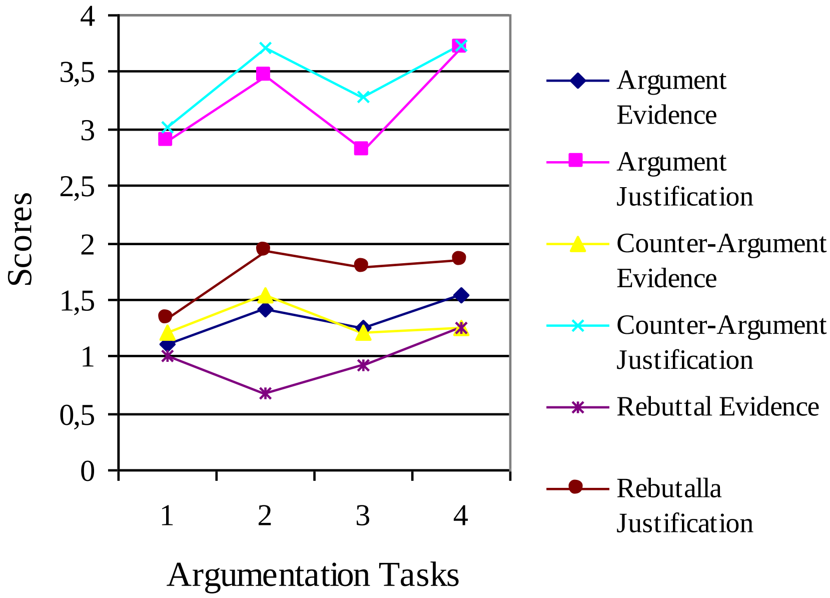

Figure 3: SHAS group's argumentation skills' mean change over argumentation tasks

A repeated measures MANOVA was performed to examine the change of argumentation skills of each group before balancing instruction. In these analyses, time (AT_1, AT_2) was the within subject factor and argumentation skills were the dependent variables. The result of the first MANOVA showed overall SHAM group's argumentation skills changed significantly over time (F (6, 12) = 6.01, $p < .01$). As can be seen in Tab.11, follow-up ANOVA results demonstrated that argument evidence and justification, counter-argument and rebuttal evidence did not contribute to this change ($p > .05$ for each analysis). However counter-argument and rebuttal justification scores increased over time ($p < .05$; $p < .001$ respectively). The result of the second MANOVA displayed that SHAS group's argumentation skills changed significantly between two argumentation tasks (F (6, 13) = 3.03, $p < .05$). As can be seen in Tab. 11, although argument evidence and justification, counter-argument evidence and justification, and rebuttal evidence scores did not change ($p > .05$ for each analysis), only rebuttal justification scores ($p < .05$) developed according to the results of follow-up ANOVAs.

	SHAM			SHAS		
	F	*df*	*p*	*F*	*df*	*p*
Argument Evidence	0.17	1, 17	.682	1.70	1, 18	.209
Argument Justification	0.77	1, 17	.394	1.24	1, 18	.281
Counter-Argument Evidence	2.03	1, 17	.172	2.42	1, 18	.137
Counter-Argument Justification	7.33	1, 17	.015	3.49	1, 18	.078
Rebuttal Evidence	0.32	1, 17	.579	1.13	1, 18	.301
Rebuttal Justification	27.96	1, 17	.000	6.50	1, 18	.020

Table 11: ANOVA results for change in balancing argumentation scores from AT_1 to AT_2 for SHAM and SHAS groups

A repeated measures MANOVA was performed for each group to examine change in argumentation skills of SHAM and SHAS after balancing instruction. Mauchly's test showed sphericity assumption was met for each dependent variable in each MANOVA. Result of the first MANOVA demonstrated that SHAM group's overall argumentation skills did not change significantly over time (Wilks' Λ was utilized; F (12, 6) = 2.59, $p > .05$). As can be seen in Tab. 12, argument evidence and justification, counter-argument evidence and justification, and rebuttal justification skills did not change substantially according to the results of follow-up ANOVAs ($p > .05$ *for each analysis*). Nevertheless only rebuttal evidence skills changed significantly from AT_2 through AT_4 ($p < .01$). Result of the second MANOVA also showed no change of SHAS group's overall argumentation skills over time (Wilks' Λ was utilized; F (12, 7) = 1.21, $p > .05$). Results of the follow-up ANOVA's confirmed this result for argument evidence and justification, counter-argument evidence and justification, and rebuttal evidence and justification skills ($p > .05$ for each analysis).

	SHAM			SHAS		
	F	*df*	*p*	*F*	*df*	*p*
Argument Evidence	0.28	2, 34	.760	0.51	2, 36	.602
Argument Justification	0.21	2, 34	.815	1.89	2, 36	.166
Counter-Argument Evidence	1.27	2, 34	.293	0.94	2, 36	.401
Counter-Argument Justification	0.06	2, 34	.946	0.50	2, 36	.609
Rebuttal Evidence	8.57	2, 34	.001	1.89	2, 36	.165
Rebuttal Justification	1.26	2, 34	.296	0.14	2, 36	.874

Table 12: ANOVA results for change in balancing argumentation scores from AT_2 to AT_4 for SHAM and SHAS groups

Pair-wise comparisons with Sidak adjustment to experiment-wise alpha level were performed to pinpoint the significant change of SHAM group's rebuttal evidence skill between argumentation tasks. According to the results, changes between AT_2 ($M = 0.67$) and AT_4 ($M = 1.50$, $p < .01$), and AT_3 ($M = 0.89$) and AT_4 were significant ($p < .05$). No significant change was observed between AT_2 and AT_3 ($p > .05$).

Discussion

This study had two research aims. First we wanted to investigate if an argumentation-based guided inquiry physics course helped PSSTs develop their argumentation skills. Then we aimed to examine the interaction between conceptual knowledge and change in argumentation skills for SHAM and SHAS groups. Accordingly, argumentation skills of PSSTs were assessed for written balancing and buoyancy argumentation tasks which were administered four times during the course (AT_1, AT_2, AT_3, AT_4) simultaneously.

PSSTs in this study were able to develop their argumentation skills, particularly the skills related to reasoning for the other alternative, during this argumentation-based guided inquiry course. More clearly, these results show that it is possible to develop *knowledge of elements of thinking* (Zohar, 2013) among PSSTs in introductory science courses. This knowledge then may be supplemented by pedagogical knowledge about argumentation during science teaching methods courses in senior college years so that PSSTs would be better equipped with argumentation pedagogy.

PSSTs' use of data and their reasoning were fostered during the guided inquiry component of the PbI course. However no special attention was paid to reasoning between alternatives during guided inquiry. Therefore it is more likely that the increase found for counter-argument and rebuttal skills is the effect of the socio-cognitive process of argumentation PSSTs practiced during argumentation component of this course.

PSSTs developed their counter-argument and rebuttal justification skills as soon as they gained the necessary conceptual knowledge which they used in their argumentation. These results are in accordance with the findings of Acar (2008). Inspired by Nussbaum and Edwards (2011), these results suggest that PSSTs had an existing argumentation schema which included slots for counter-arguments and rebuttals and these were filled during PSSTs' engagement with argumentation and their acquisition of relevant conceptual knowledge. In spite of these encouraging results, neither SHAM nor SHAS group's argument skills developed. We propose two possible explanations for this result. First the importance of one's own position in argumentation process may not have been adequately addressed in this argumentation-based guided inquiry course. In other words, PSSTs' argumentation schema had a slot for argument but this was not adequately activated in the course. Second PSSTs might not have felt the need for making a persuasive argument for a normative explanation because they might have thought that its correctness was apparent to others.

The SHAM group developed counter-argument and rebuttal justification skills and SHAS group developed only rebuttal justification skill related to balancing between AT_1 and AT_2. At this point, it should be noted that SHAM changed their arguments from nonnormative to normative position at AT_2. The SHAM group may not have found it hard to construct counter-arguments for nonnormative position at AT_2 because they already had the argumentation schema which included a filled slot for counter-argument. We speculate that the SHAS group could not develop counter-arguments for nonnormative explanation because although they might have had the argumentation schema which included a counter-argument slot, they might not have possessed necessary conceptual links in the nonnormative explanation. Further the SHAS group might have had trouble to distance themselves long enough from their explanation to consider a counter-argument (Nussbaum & Kardash, 2005). Development of both groups' rebuttal justification skill as soon as they received instruction on balancing suggests that PSSTs had an existing argumentation schema that included a slot for rebuttal and this was activated after PSSTs learned the topic in the course. We suppose from these results that one needs to learn sufficient conceptual knowledge regarding normative explanation for making a qualified rebuttal justification against the nonnormative explanation.

The result regarding the development of rebutting a nonnormative position would be appreciated within science education community but how can we interpret the result related to the development of counter-arguments for a normative position? Approximately half of the sample argued for an alternative explanation of balancing at the beginning of the course. SHAM developed counter-argument and rebuttal justification skills as soon as they received balancing instruction and rebuttal evidence skill after they received balancing instruction. Development of both counter-argument and rebuttal skills implies that SHAM recognized the limitation of the naïve explanation over the course. We argue from these results that by counter-arguing, SHAM better comprehended the limitations of the naïve explanation and appreciated the scientific explanation of balancing which cannot be solely attributed to their conceptual knowledge development during the course. Development of SHAM group's rebuttal evidence skill after balancing instruction supports this explanation.

Only SHAM group developed their rebuttal evidence skill after they had received balancing instruction. We suggest that CTTS, which was utilized several times, motivated SHAM to rebut a nonnormative explanation of which they knew the limitations more than SHAS. Rebuttal justification skill did not develop because PSSTs did not receive balancing instruction after AT_2. Moreover, SHAS group was not motivated as much as SHAM to rebut the nonnormative explanation in this argumentation-based inquiry course and as a consequence no rebuttal skill development was observed for this group.

Study Limitations

Since we did not have a comparison group, we cannot claim that results of this study are due to the sole effect of argumentation-based inquiry course. To examine the effect of this kind of instruction on argumentation skills of PSSTs, formation of a control group is necessary. In addition, we examined the interaction of the change in argumentation skills with conceptual knowledge development during the instruction for only one concept. Thus, our results should be viewed as preliminary for this research focus. Future research can examine this issue with multiple concepts.

Implications

This study showed that argumentation skills of PSSTs, particularly skills related to reasoning between alternative explanations, can be developed in an argumentation-based guided inquiry course. More specifically, instructional approach taken in this study in the form of written and teacher scaffolds which fostered PSSTs' use of evidence and justifications, and reasoning between different positions helped PSSTs develop their argumentation skills. Fostering argumentation among PSSTs is particularly important because they would be more skilful in scaffolding their students' argumentation if they are better equipped with these skills (Avraamidou & Zembal-Saul, 2010). Thus, more argumentation learning opportunities in introductory science courses should be provided so that PSSTs can practice argumentation skills earlier which would affect their beliefs about argumentation pedagogy in a positive direction.

CTTS utilized in this study did not help both SHAM and SHAS develop their argument skills. We recommend educators to stress the importance of qualified scientific arguments more in their science classes. In addition, our results suggest that counter-argument and rebuttal justification skills of SHAM and SHAS developed as soon as each group learned the scientific content of their argumentation. This result demonstrates the importance of conceptual knowledge gain in the development of these skills. SHAM group was more motivated to argue about the nonnormative explanation than SHAS group. We think that tentative aspect of nature of science should be more emphasized in science classes so that PSSTs can comprehend that there is no absolute correct theory but all theories undergo by a process of refutation (Popper, 1968).

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Appendix A

A Written Argumentation Task

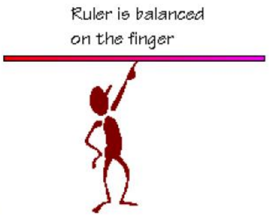
Two students were having a discussion about the concept of balancing. Below are their explanations for the concept of balancing.

Student A : Masses should be equal on both sides of the balance. If the object is symmetric, then the fulcrum is at the center which makes the two sides equal and balanced. If the object is asymmetric, then the fulcrum gets closer to the more massive part making both sides of the balance have equal masses.

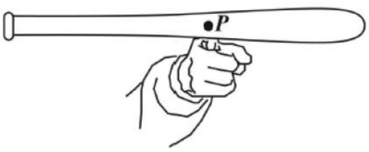
Student B : Balancing depends on the distance of the sides from the fulcrum and the masses on each side. If the mass of one side is bigger than the other side then that side should have less distance from the fulcrum compared to the other side.

Another friend provided some observations about their discussion. These observations were ;

1. A tightrope walker balances on a rope.



2. A symmetric ruler balances on a person's finger.



3- A baseball bat balances on a person's finger.

4- A huge cup is placed at the left end of the seesaw. Three people who have equal masses balance this cup. The first person is at the right end of the seesaw.

Questions:

1.a. Which observations do you think student A would use to support his/her position?

b. Which observations do you think student B would use to support his/her position?

2.a. What would student A's justifications be to use these observations in his/her argument?

b. What would student B's justifications be to use these observations in his/her argument?

3. a. Which of the students do you agree with or do you have another argument? Explain your reasoning using observations.

b. If you agree with student A, explain your reasoning for not choosing student B. Specifically, which observations do not fit with student B's argument and why?

c. If you agree with student B, explain your reasoning for not choosing student A. Specifically, which observations do not fit with student A's argument and why?

d. If you have another argument, explain your reasoning for not choosing either student A or student B. Specifically, which observations do not fit with student A's and student B's arguments and why?

Appendix B

	AT_1		AT_2		AT_3		AT_4	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Argument Evidence	1.50	0.70	1.39	0.92	1.42	0.84	1.22	0.94
Argument Justification	3.81	1.41	3.36	1.71	3.35	1.66	3.06	1.36
Counter-Argument Evidence	1.44	0.70	1.72	0.57	1.39	0.50	1.53	0.78
Counter- Argument Justification	2.75	1.30	3.79	1.43	3.76	1.26	3.89	1.56
Rebuttal Evidence	0.50	0.86	0.67	0.91	0.89	0.90	1.50	0.86
Rebuttal Justification	0.75	0.26	1.68	0.65	1.46	0.79	1.82	0.91

Table B1: Descriptive statistics of SHAM group's argumentation skills over argumentation tasks

	AT_1		AT_2		AT_3		AT_4	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Argument Evidence	1.11	0.74	1.42	0.90	1.26	0.65	1.53	0.84
Argument Justification	2.89	1.58	3.47	1.80	2.82	1.16	3.71	1.83
Counter-Argument Evidence	1.21	0.71	1.53	0.77	1.21	0.63	1.26	0.81
Counter- Argument Justification	3.01	1.41	3.71	1.54	3.29	1.53	3.74	1.73
Rebuttal Evidence	1.00	0.94	0.68	0.95	0.92	0.98	1.26	0.99
Rebuttal Justification	1.34	0.80	1.92	0.67	1.79	0.73	1.84	0.83

Table B2: Descriptive statistics of SHAS group's argumentation skills over argumentation tasks